Executive Summary

What is the Estuary Recovery Module?

This estuary recovery plan module is one element of a larger planning effort led by the National Marine Fisheries Service (NMFS, also known as NOAA Fisheries) to develop recovery plans for Endangered Species Act-listed salmon and steelhead trout in the Columbia River basin. Recovery plans are being developed for each of the listed 13 evolutionarily significant units (ESUs) in the Columbia.[1] Figure ES-1 shows the 13 listed ESUs in the Columbia River basin grouped by region. The regions include the Lower Columbia, Upper Willamette, Middle Columbia, Snake, and Upper Columbia River ESUs. Within each of the regions, the ESUs have unique geographical boundaries that are based on similarities among populations.

This estuary recovery plan module complements other recovery plans in the region. With few exceptions, the module's focus is limited to habitat conditions and processes in the Columbia River estuary and plume, rather than hatchery or harvest practices, hydroelectricity production, or tributary habitats in the Columbia River basin. The goal of the module is to identify and prioritize management actions that, if implemented, would reduce the impacts of the limiting factors that salmon and steelhead encounter during migration and rearing in the estuary and plume ecosystems. To accomplish this, changes in the physical, biological, or chemical conditions in the estuary are reviewed for their potential to affect salmon and steelhead. Then, the underlying causes of limiting factors are identified and prioritized based on the significance of the limiting factor and each cause's contribution to one or more limiting factors. These causes are referred to as threats and can be either human or environmental in origin. Finally, management actions are identified that are intended to reduce the threats and increase the survival potential of salmon and steelhead during estuarine rearing and migration. Costs are developed for each of the actions using an estimated level of effort to implement actions.

This estuary recovery plan module is intended to help answer questions about the degree to which the estuary and plume can contribute to salmon and steelhead recovery efforts throughout the Columbia River basin. The state of the science surrounding the estuary and plume is such that quantitative answers to questions about estuarine ecology are not necessarily available at this time. This is true in part because of the complexity of the ecological processes in the estuary and plume. However, it is also true because the Columbia River estuary and plume are only now being studied at a level of detail that allows knowledge about this portion of the Columbia River ecosystem to be integrated into the understanding of life history patterns that have been well documented in the upstream portions of the basin.

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[1] NOAA Fisheries has revised its species determinations for West Coast steelhead under the Endangered Species Act (ESA), delineating steelhead-only "distinct population segments" (DPSs). The former steelhead ESUs included both anadromous steelhead trout and resident, non-anadromous rainbow trout, but NOAA Fisheries listed only the anadromous steelhead. The steelhead DPS does not include rainbow trout, which are under the jurisdiction of the U.S. Fish and Wildlife Service. In January 2006, NOAA Fisheries listed five Columbia River basin steelhead DPSs as threatened (71 FR 834). To avoid confusion, references to ESUs in this estuary recovery plan module imply the steelhead DPSs as well.

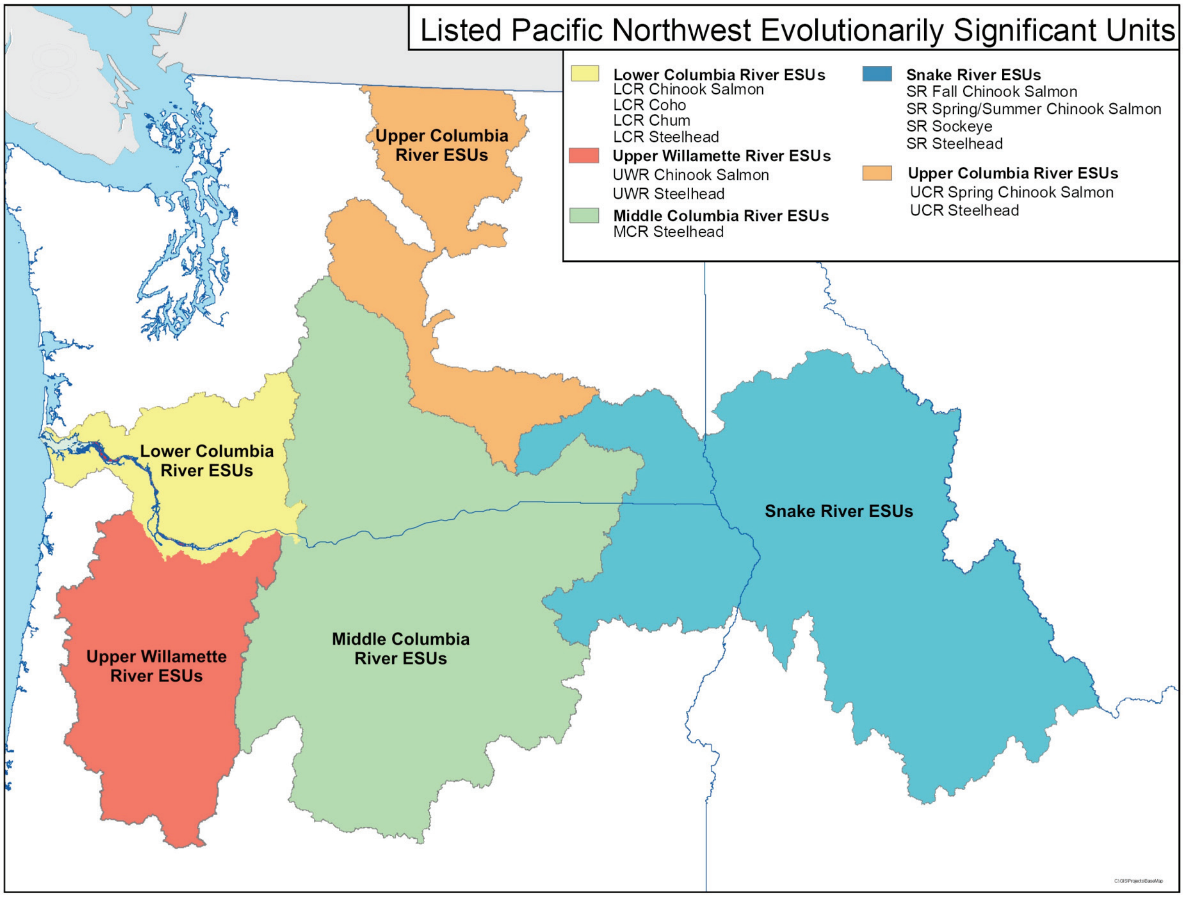

FIGURE ES-1
Listed Pacific Northwest ESUs

This estuary recovery plan module is a synthesis of diverse literature sources and the direct input of estuary scientists. Several key documents were used extensively as a platform for the module because of the similarities in their purpose and content. One of those documents is the "Mainstem Lower Columbia River and Columbia River Estuary Subbasin Plan," which, along with its supplement, was developed by the Lower Columbia River Estuary Partnership for the Northwest Power and Conservation Council's *Columbia River Basin Fish and Wildlife Program* (Northwest Power and Conservation Council 2004). In 2005, NOAA/NMFS's Northwest Fisheries Science Center produced two important technical memoranda for the estuary: *Salmon at River's End* (Bottom et al. 2005) and *Role of the Estuary in the Recovery of Columbia River Basin Salmon and Steelhead* (Fresh et al. 2005). These two memoranda also were used extensively. Other sources were consulted as well, including many primary sources. Area experts from NOAA/NMFS's Northwest Fisheries Science Center, other NMFS staff, Lower Columbia River Estuary Partnership staff, and the Lower Columbia Fish Recovery Board provided input and advice on scoring and evaluation processes. Additionally, modifications to the estuary recovery plan module were influenced by interactions with the Northwest Power and Conservation Council, the Mid-Columbia Sounding Board, the Upper Willamette Recovery Planning Stakeholder Team, and the Lower Columbia River Recovery Planning Stakeholder Team.

Why Are the Estuary and Plume Important?

The Columbia River estuary and plume represent one of three major stages in the life cycle of salmon and steelhead. In tributaries, adults spawn and juveniles rear in freshwater. In the ocean, juveniles grow to adults as they forage in food-rich environments. The estuary is where juveniles and adults undergo vast physiological changes needed to transition to and from saltwater. In addition, a properly functioning estuary provides high growth opportunities and refugia from predators.

But why are the estuary and plume so important? The answer lies in the very reason that salmonids grew in numbers to an estimated 16 million over the past 4,000 years. Salmon and steelhead were successful because they exploited a wide array of the habitat niches available to them. They did this by employing a variety of strategies that allowed them to use many diverse habitats across a wide geographic space. In fact, the distribution of salmon and steelhead historically spanned thousands of river miles throughout the basin.

If this were not remarkable enough, salmon and steelhead's traits allowed them to use habitats at varying times, and this is one of the primary reasons the estuary and plume are so important. Every downstream-migrating juvenile salmon or steelhead must use the habitats of the estuary to complete its life cycle. If the progeny of the 16 million adult salmon and steelhead that historically made use of the estuary had converged on the estuary at one time, there likely would not have been enough habitat and food to sustain them. So they developed strategies to enter the estuary at different times, at different sizes, using unique habitats. In fact, it has been hypothesized that each individual population's use of estuarine habitats is discrete in terms of time and location of use. The implication of this for the estuary and plume today is that the area's habitats must be available through time and space and at sufficient quantities to support more than 150 distinct salmon and steelhead populations, which represent 13 ESUs that use many diverse life history strategies.

The number of adult salmon and steelhead that return to the Columbia River basin each year varies, but in recent years, average returns have been about 1.7 million, with approximately 65 to 75 percent of those fish being of hatchery origin.[2] For 2006, NOAA Fisheries scientists estimated that about 168 million juveniles would enter the estuary (Ferguson 2006b). This suggests that only 1 percent of the juveniles entering the estuary will return as adults and 99 percent are lost as a result of all the limiting factors (human and natural) in the estuary, plume, nearshore, and ocean. Understanding the extent to which the estuary and plume contribute to these losses is essential to the ultimate recovery of salmon and steelhead ESUs throughout the basin.

What Is the Condition of the Estuary Now?

Flows, Dikes and Filling, Sediment, and Temperature

The estuary and plume are considerably degraded compared to only 200 years ago. In terms of absolute size, the estuary tidal prism is about 20 percent smaller than it was when Lewis and Clark camped along the Columbia's shore (Northwest Power and Conservation Council 2004). This reduction in estuary size is due mostly to dike and filling practices used to

[2] This is an informal estimate made by several knowledgeable experts; determining the ratio of hatchery-origin fish with more certainty would require stock-by-stock run calculations averaged over many years.

convert the floodplain to agricultural, industrial, commercial, and residential uses. Instream flows entering the estuary also have changed dramatically—there has been a 44 percent decrease in spring freshets or floods, and the annual timing, magnitude, and duration of flows no longer resemble those that historically occurred in the Columbia River (Jay and Kukulka 2002). Changes to flow volume and timing are attributed to flow regulation by the hydrosystem, water withdrawal for irrigation and water supplies, and climate fluctuations.

Flow alterations and dike and filling practices are significant to salmon and steelhead in several ways. Historically, vegetated wetlands within the floodplain supplied the estuary with its base-level food source: macrodetritus. The near elimination of overbank events and the separation of the river from its floodplain have altered the food web by reducing macrodetrital inputs by approximately 84 percent (Bottom et al. 2005). At the same time, phytoplankton detrital sources from upstream reservoirs now dominate the base of the food chain. The substitution of food sources likely has profound effects on the estuary ecosystem. In addition, access to and use of floodplain habitats by ocean-type ESUs (salmonids that typically rear for a shorter time in tributaries and a longer time in the estuary) have been severely compromised through alterations in the presence and availability of these critical habitats.

The timing, magnitude, and duration of flows also have important ramifications to in-channel habitat availability and connectivity. Sand transport along the river bottom is highly correlated to flow. With reductions in the magnitude and duration of flows, erosion and accretion processes no longer function as they have for thousands of years. This may have far-reaching consequences to the estuary, plume, and nearshore lands north and south of the river's mouth. At the same time, upstream dams have prevented sediments from entering the estuary, while dredging activities have exported sand and gravel out of the estuary. Studies have shown that sand is exported from the estuary at a rate three times higher than that at which it enters the estuary. The full impact of these changes is unknown; however, sediment transport is a primary habitat-shaping force that determines the type, location, and availability of habitats distributed in the estuary and plume. Recent bathymetry modeling efforts and new research on juvenile salmonid use of estuary habitats will help characterize juvenile mortality in the near future. Decreases in sediments also improve water clarity and increase the effectiveness of predators that consume juvenile and adult salmon and steelhead.

Elevated temperatures of water entering the estuary are a threat to salmon and steelhead. Summer water temperatures entering the estuary are on average 4 degrees warmer today than they were in 1938 (Lower Columbia Fish Recovery Board 2004). The upper range for cold-water fish, including salmon and steelhead, is about 20° to 24° Celsius. Temperatures exceeding this threshold have been occurring earlier in the year and more frequently since 1938 (as measured at Bonneville Dam). Degradation of tributary riparian habitat caused by forest, residential, commercial, and industrial practices, as well as reservoir heating, is responsible for increased temperatures.

Water Quality

Water quality in the estuary and plume has been degraded by human practices from within the estuary and also from upstream sources. An important indicator of water quality degradation found in the estuary is the presence of toxic contaminants. A recent study of contaminant impacts on juvenile salmon estimated delayed disease-induced mortalities of

1.5 and 9 percent as a result of contaminant stressors for residencies in the Columbia River estuary of 30 to 120 days, respectively (Loge et al. 2005). If this estimate is accurate, threats from contaminants may exceed those from Caspian tern predation.

Many contaminants are found in the estuary and plume. Some of them are water-soluble agricultural pesticides and fertilizers such as simazine, atrazine, and diazinon. Industrial contaminants include polycyclic aromatic hydrocarbons (PAHs) and polychlorinated biphenyls (PCBs). Concentrations of these substances, and others, are found throughout the estuary, sometimes near cities and other times in bays and shallows where low-velocity flows allow suspended contaminants to settle. Salmon and steelhead are affected by contaminants through short-term exposure to lethal substances or through longer exposures to chemicals that accumulate over time and magnify through the food chain. Ocean-type ESUs are more susceptible to bioaccumulation than stream-type ESUs; however, both are equally vulnerable to acute exposures (stream-type ESUs are those ESUs that typically spend longer periods in tributaries and less time in the estuary).

Food Web and Species Interactions

The Columbia River estuary represents a distinct ecosystem that is a unique expression of biological and physical interactions. As physical and biological changes occur in the estuary, the ecosystem responds to those changes. There is general agreement that the estuary ecosystem is degraded and no longer provides the same level of support to native species assemblages that it did historically. Unfortunately, this field of research is perhaps the least understood, and its impact on salmon and steelhead is not well documented or studied.

Limiting factors related to the food web and species interactions can be thought of as the product of all the threats to salmon and steelhead in the estuary. Some examples are easy to understand, but others are subtle and far-reaching. Caspian terns are a good example of an ecosystem shift that is easy to understand. New islands formed through the disposal of dredged materials attracted terns away from their traditional habitats, which may be being degraded. Reduced sediment in the river increased terns' efficiency in capturing steelhead juveniles migrating to saltwater at the same time that the birds need additional food for their broods. The result is a predator/prey shift in the estuary that has increased mortality for steelhead juveniles. Double-crested cormorants also prey on juvenile salmonids, in similar numbers as terns.

Other shifts in the ecosystem are more complex, and it can be difficult to understand whether or how they affect salmon and steelhead. For example, the shift from macrodetritus-based primary plant production to phytoplankton production strikes at the most elemental level of the food chain in the estuary; however, what this means to salmon and steelhead—or, for that matter, to the entire estuary ecosystem—is unknown. The introduction of exotic species is another poorly understood ecosystem alteration. Examples of exotic species thriving in the estuary include 21 new invertebrates, plant species like Eurasian water milfoil, and exotic fish like shad. Shad in particular, because of the sheer tonnage of their biomass, undoubtedly play a large role in the degradation of the estuary ecosystem.

Other Threats

The estuary also is influenced by a number of physical structures that contribute to its overall degradation, but the extent of their impacts to salmon and steelhead is poorly understood. Structures in the estuary number in the thousands. Over-water and instream structures alter river circulation patterns, sediment deposition, and light penetration, and they form microhabitats that often benefit predators. In some cases, structures reduce juvenile access to low-velocity habitats. Examples of structures include jetties, pilings, pile dikes, rafts, docks, breakwaters, bulkheads, revetments, groins, and ramps.

Ship wake stranding is an example of another threat to salmon and steelhead in the estuary. A study in 1977 by the Washington Department of Fisheries estimated that more than 150,000 juvenile salmonids, mostly chinook, were stranded on five test sites as a result of ship bow waves striking shorelines (Bauersfeld 1977). Additional studies since the Bauersfeld study have not documented the same level of mortality. Light Detection and Radar (LIDAR) analysis and results from a new study by the University of Washington and the Portland District of the U.S. Army Corps of Engineers may help characterize this threat in the near future. This threat is most detrimental to ocean-type juvenile fry that are less than 60 millimeters long and rear inches from shore.

What Can We Do to Improve Salmon and Steelhead Survival?

Identification of Management Actions and Monitoring Activities

This estuary recovery module identifies 23 management actions to improve the survival of salmon and steelhead migrating through and rearing in the estuary and plume environments. Table ES-1 lists these management actions and shows their relationship to threats to salmonid survival.

TABLE ES-1
Management Actions to Address Threats

	Threat	Management Action
Flow-related threats	Climate cycles and global warming[2]	**CRE[1]-1:** Protect intact riparian areas in the estuary and restore riparian areas that are degraded.[2] **CRE-2:** Operate the hydrosystem to reduce the effects of reservoir surface heating, or conduct mitigation measures.[2] **CRE-3:** Establish minimum instream flows for the estuary that would help prevent further degradation of the ecosystem.[2]
	Water withdrawal	***CRE-3:** Establish minimum instream flows for the estuary that would help prevent further degradation of the ecosystem.*
	Flow regulation	**CRE-4**: Adjust the timing, magnitude and frequency of flows (especially spring freshets) entering the estuary and plume to provide better transport of coarse sediments and access to habitats in the estuary, plume, and littoral cell.
Sediment-related threats	Entrapment of fine sediment in reservoirs	**CRE-5:** Study and mitigate the effects of entrapment of fine sediment in reservoirs, to improve nourishment of the littoral cell.
	Impaired transport of coarse sediment	**CRE-8:** Remove pilings and pile dikes with low economic value when removal clearly would improve ecosystem health. **CRE-6:** Reduce the export of sand and gravels via dredge operations by using dredged materials beneficially. ***CRE-4:** Adjust the timing, magnitude and frequency of flows (especially spring freshets) entering the estuary and plume to provide better transport of coarse sediments and access to habitats in the estuary, plume, and littoral cell.*

	Dredging	**CRE-7:** Reduce entrainment and habitat effects resulting from main- and side-channel dredge activities in the estuary.
Structural threats	Pilings and pile dike structures	**CRE-8:** Remove pilings and pile dikes with low economic value when removal clearly would improve ecosystem health.
	Dikes and filling	**CRE-9:** Protect remaining high-quality off-channel habitat from degradation. **CRE-10:** Breach or lower dikes and levees to improve access to off-channel habitats.
	Reservoir-related temperature changes	***CRE-2:*** *Operate the hydrosystem to reduce the effects of reservoir surface heating, or conduct mitigation measures.*
	Over-water structures	**CRE-11:** Reduce the square footage of over-water structures in the estuary.
Food web-related threats	Reservoir phytoplankton production	***CRE-10:*** *Breach or lower dikes and levees to improve access to off-channel habitats.*
	Altered predator/prey relationships	**CRE-13:** Manage pikeminnow and other piscivorous fish, including introduced species, to reduce predation on salmonids. **CRE-14:** Identify and implement actions to reduce salmonid predation by pinnipeds. **CRE-15:** Implement education and monitoring projects and enforce existing laws to reduce the introduction and spread of noxious weeds. **CRE-8:** Remove pilings and pile dikes with low economic value when removal clearly would improve ecosystem health. **CRE-16:** Implement projects to redistribute part of the Caspian tern colony currently nesting on East Sand Island. **CRE-17:** Implement projects to reduce double-crested cormorant habitats and encourage dispersal to other locations. **CRE-18:** Reduce the abundance of shad in the estuary.
	Ship ballast practices	**CRE-19:** Prevent new invertebrate introductions and reduce the effects of existing infestations.
Water quality-related threats	Agricultural practices	***CRE-1:*** *Protect intact riparian areas in the estuary and restore riparian areas that are degraded.* ***CRE-9:*** *Protect remaining high-quality off-channel habitat from degradation.* **CRE-20:** Implement pesticide and fertilizer best management practices to reduce estuary and upstream sources of toxic contaminants entering the estuary.
	Urban and industrial practices	***CRE-9:*** *Protect remaining high-quality off-channel habitat from degradation.* **CRE-21:** Identify and reduce industrial, commercial, and public sources of pollutants. **CRE-22:** Monitor the estuary for contaminants and/or restore contaminated sites. **CRE-23:** Implement stormwater best management practices in cities and towns. ***CRE-1:*** *Protect intact riparian areas in the estuary and restore riparian areas that are degraded.*
Other threats	Riparian practices	***CRE-1:*** *Protect intact riparian areas in the estuary and restore riparian areas that are degraded.*
	Ship wakes	**CRE-12:** Reduce the effects of vessel wake stranding in the estuary.

[1] CRE = Columbia River estuary.

[2] It is unclear what the regional effects of climate cycles and global warming will be during the coming decades. In the absence of more definitive data on the future effects of climate cycles and global warming in the Pacific Northwest, this recovery plan module takes a conservative approach of assuming reduced snowpacks, groundwater recharge, and stream flows, with associated rises in stream temperature and demand for water supplies. The climate-related management actions in Table 5-1 reflect this assumption. Although the management actions clearly would not change the threat itself, they have the potential to lessen its impact on salmonids in the estuary. Even if climate cycles and global warming have effects different from those assumed in this document, the management actions that Table 5-1 associates with climate would provide benefits to salmonids by addressing other threats, such as water withdrawal, urban and industrial practices, and reservoir heating. All three of the management actions associated with climate in Table 5-1 are associated with other threats listed in Table 5-1.

Note: Italics indicate an action's second occurrence in the table, in connection with a different threat.

Monitoring, research, and evaluation (MR&E) activities appropriate to the 23 management actions are in the process of being identified and will be included in the module at a later date. Some of these activities are already described as part of the draft *Federal Columbia River Estuary Research, Monitoring, and Evaluation Program* (Johnson et al. 2006), while other activities will be identified that are specific to the management actions in the module. Together, the existing and new MR&E activities will provide crucial information on the effectiveness of actions that are implemented in the estuary, associated changes in the ecology of the estuary, and scientific uncertainties that affect implementation of the actions.

Evaluating Management Actions: Relationship of Implementation Constraints to Cost and Survival Improvements

Identifying management actions that could reduce threats to salmon and steelhead as they rear in or migrate through the estuary is an important step toward improving conditions for salmonids during a critical stage in their life cycles. However, actual implementation of management actions is constrained by a variety of factors, such as technical, economic, public health and safety, and property rights considerations. In fact, in some cases it will be impossible to realize an action's full potential because its implementation is constrained by past societal decisions that are functionally irreversible. Reclaiming off-channel habitats in the lower Cowlitz River floodplain, for example, is constrained by the development of the city of Longview decades ago. An important assumption of the estuary recovery plan module is that the implementation of each of the 23 management actions identified in the module is constrained in some manner.

The module makes another important assumption about implementation: although implementation of actions is constrained, even constrained implementation can make important contributions to the survival of salmonids in the estuary, plume, and nearshore.

It is within the context of these two fundamental assumptions that recovery actions are evaluated in the module, in terms of their costs and potential benefits. The evaluation of survival benefits and costs is highly uncertain because it relies on estimates not only of what is technically feasible, but also of what is socially and politically practical. To help characterize survival improvements, the estuary recovery module uses a planning exercise that involves distributing a plausible survival target across the actions to hypothesize a potential amount of improvement that would result from each action. Costs then are developed by identifying projects for each action and units and per-unit costs for each project. Both the survival improvements and costs reflect assumptions about the constraints to implementation and the degree to which those constraints can be reduced given the technical, social, and political context in the Columbia River basin.

Evaluation Results

The estuary recovery plan module estimates that the cost of partial (constrained) implementation of all 23 actions over a 25-year time period is about $500 million. The $500 million estimate in this estuary recovery plan module represents an order-of-magnitude increase over the current level of investment in the estuary and reflects a significant level of effort needed to improve ecosystem health in the estuary, plume, and nearshore over the next 25 years.

Table ES-2 shows the most important management actions for ocean- and stream-type salmonids that emerged from the analysis and planning exercises in the estuary recovery plan module. Many of these actions are the same for ocean and stream types.

TABLE ES-2
Management Actions Important for Survival of Ocean- and Stream-type Salmonids

For Ocean Types	For Stream Types
CRE-01: Protect/restore riparian areas.	CRE-01: Protect/restore riparian areas.
CRE-04: Adjust the timing, magnitude, and frequency of flows.	CRE-04: Adjust the timing, magnitude, and frequency of flows
CRE-08: Remove pilings and pile dikes.	CRE-08: Remove pilings and pile dikes.
CRE-09: Protect remaining high-quality off-channel habitat.	CRE-09: Protect remaining high-quality off-channel habitat.
CRE-10: Breach or lower dikes and levees.	CRE-10: Breach or lower dikes and levees.
CRE-13: Manage pikeminnow and other piscivorous fish.	CRE-13: Manage pikeminnow and other piscivorous fish.
CRE-21: Identify and reduce sources of pollutants.	CRE-21: Identify and reduce sources of pollutants.
CRE-22: Monitor and restore contaminated sites.	CRE-22: Monitor and restore contaminated sites.
CRE-02: Mitigate/reduce reservoir-related temperature changes.	***CRE-14: Reduce predation by pinnipeds.***
	CRE-16: Redistribute Caspian terns.
	CRE-17: Redistribute cormorants.

Note: Bold-face italics indicate management actions that would benefit primarily ocean- or stream-type salmonids, rather than both types.

Implementing the suite of actions in Table ES-2 for ocean-type salmonids would cost approximately $386 million and be expected to achieve approximately 88 percent of the survival target (see Chapter 5 for a description of survival targets) for ocean-type juveniles. Implementing the suite of actions for stream-type salmonids would cost approximately $402 million and be expected to achieve 90 percent of the survival target. Additionally, a gain of 5,000 adult stream types (spring chinook and winter steelhead) is associated with the implementation of CRE-14, “Reduce predation by pinnipeds.” The lists of priority actions in Table ES-2 for ocean- and stream-type salmonids contain eight actions that are predicted to benefit both types of salmonids. Implementing this common set of actions would cost approximately $366 million and would be expected to yield survival improvements of roughly 3 million juveniles.

Other Implementation Considerations: Life History Diversity, Cost-Effectiveness, and Achieving Maximum Benefit

It is tempting to pick and choose among the management actions, looking for the path of least resistance to achieve the desired survival improvements. For example, using the results of the Chapter 7 survival improvement planning exercise, it appears obvious that significant improvements in the survival of stream-type salmonids can be achieved by reducing threats associated with predators such as terns, cormorants, pikeminnow, and pinnipeds. However, addressing these threats would improve survival primarily for the dominant life-history strategy displayed by stream-type salmonids; in terms of recovery of ESUs, less dominant stream-type life history strategies also must be addressed. This points to the need to implement additional management actions in the estuary not directly related to predation.

For ocean-type juveniles, management actions that improve the health of the estuarine ecosystem appear to be the linchpin. Ocean-type juveniles reside in the estuary longer than stream types do and, as a result, rely more heavily on a healthy estuarine ecosystem to provide them with food and habitat. Given the challenges of making wide-scale ecosystem change, significant improvements for ocean-type juveniles may depend largely on three of the most constrained actions: adjusting flows (CRE-4), breaching or lowering dikes and levees to increase access to off-channel habitats (CRE-10), and restoring contaminated sites (CRE-22). Although these are some of the most expensive actions, their effects could be far-reaching enough that their potential benefits would be at least commensurate with their high costs.

Finally, because the estuary recovery module (by design) takes an optimistic view about what is possible in terms of reducing the constraints to implementation of management actions, in actuality specific actions probably will not be implemented with the level of effort needed to elicit the desired response. In fact, the most important take-home message of the estuary plan module is that recovery of listed ESUs in the Columbia River may not be possible without properly functioning estuary, plume, and nearshore ecosystems; to achieve a meaningful boost in survival from these ecosystems, every ounce of an action’s potential benefit should be explored, and serious consideration should be given to implementing all of the 23 management actions to the fullest extent possible.